11 Aristotle and His Teacher

The fate of empires depends on the education of youth.
—Aristotle (384–322 B.C.E.), Greek philosopher

Whereas the rattle is a suitable occupation for infant children, education serves as a rattle for young people when older.
—Aristotle, *Politics*

Amicus Plato, sed magis amica veritas. ("Plato is dear to me, but dearer still is truth.")
—Latin words ascribed to Aristotle, who said them in Greek

By the time Aristotle came along—almost 200 years after Pythagoras—sky gazers had figured out that the round shape on the Moon during a lunar eclipse is our planet's shadow. Since those sky gazers were apt to be the wisest of scholars, it was a heavy nail in the flat-Earth coffin.

There were others. The Greeks traveled widely in the Mediterranean lands. They knew that the North Star is lower in the sky in southern Egypt than it is in northern Greece. A round Earth explains that. And they also knew that the first one sees of a ship coming over the horizon is its sail; only later does the hull come into view. That seemed to confirm the round-world theory.

But other puzzles in the sky needed answering. Aristotle rolled up his sleeves—well, that may have been difficult in a flowing toga—or whatever he did, and he got to work.

Aristotle was another brainy Greek, perhaps the brainiest of them all. When he was born, in 384 B.C.E., Greece was in the midst of a period of creativity that would change the world forever. (It's known as Greece's classic period.)

An astronomer friend tells me sky gazers *still are* the wisest of scholars!
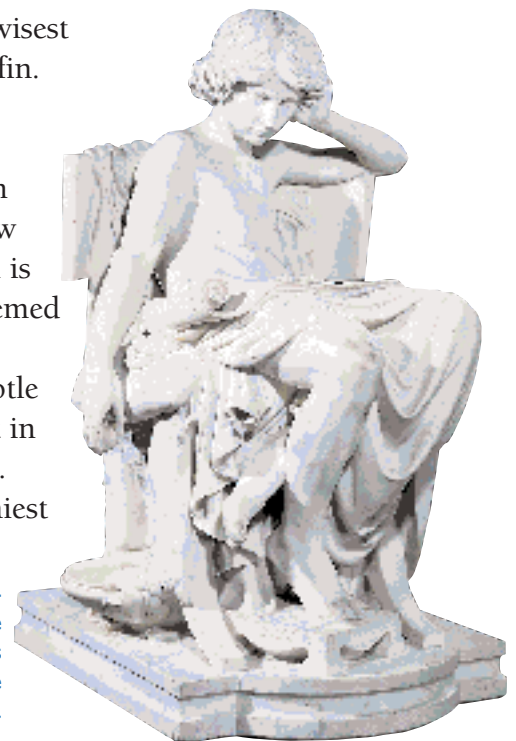
A nineteenth-century marble sculpture captures a young Aristotle lost in thought.

The Earth's shadow doesn't fall on the Moon any old time. A lunar eclipse happens only during a full moon, when Earth is directly between the Sun and the Moon (see page 27). The ancient Greeks watched without telescopes as this shadow passed over the full moon (it happens in minutes) and saw that the edge was slightly curved. They concluded that Earth, like its shadow, must be curved, too.

(If this diagram were to scale, Earth would be just to the left of page 94. The Sun would be 1½ football fields beyond that and have almost a 5-foot diameter.)

Sun

Moon's orbit

Earth

umbra, or total shadow

Moon

penumbra, or partial shadow
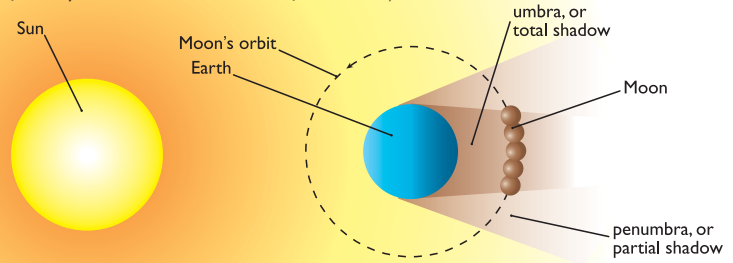
Classical Greek achievements in art, architecture, literature, and philosophy set standards of beauty and excellence that still leave us awed. We, today, are what we are in great part because of the ancient Greeks. (Look at a Greek statue from the classic period and see what you think.)

That classic period was long after Thales' time, and although the early Ionians were not forgotten, they must have seemed a bit old-fashioned. New winds were blowing: power and influence had crossed the Aegean Sea from the Ionian coast of Turkey to mainland Greece.

Aristotle was born in Stagira, a northern city located on a mountainous peninsula with fingers that extend into the Aegean Sea. He was fortunate in being able to go to good schools where he studied the work of both Thales and Pythagoras. Then, at age 18, he went off to Athens, the leading city-state in Greece, to study at the academy of the greatest philosopher of his day—Plato.

Unlike the Ionians, Plato (ca. 427–347 B.C.E.) didn't much trust his eyes and ears and other senses. If he wanted to understand something, he withdrew to the world of pure thought. Plato was looking for beauty, truth, and clarity. He didn't believe they could be found on Earth, so he urged his students to study mathematics and the stars. In both studies, he discovered patterns and order that seemed astonishing.

This series of photos shows the total lunar eclipse of January 21, 2000, which lasted for 1 hour and 18 minutes. The photos were snapped at 20-minute intervals. The Moon is in full phase throughout; the shifting darkness on its surface is the Earth's shadow. The umbra (the darkest part of the shadow) doesn't obscure the Moon completely, because Earth's atmosphere refracts (bends) some sunlight onto the Moon's surface. As the light passes through the atmosphere, the blue wavelengths scatter, so the eclipsed Moon appears orange.

A revered Greek named Academus once owned the land under Plato's Academy. Ever since, the word ACADEMY has been used for schools.

Lewis Carroll, who wrote *Alice in Wonderland*, dedicated his book *Symbolic Logic* to the memory of Aristotle, which isn't surprising: Aristotle is called the Father of Logic. Logic is a way of using the mind to solve problems. *Symbolic Logic* was written for young people. I recommend it.

Mathematics had a purity that lifted it above mundane, flawed earthly things. As to the stars, he thought they were made of different stuff from the Earth and were an example of God's perfection.

Plato was influenced by Pythagoras's mathematics, which focused on perfect shapes and perfect harmony. Plato was hooked on perfection. He thought about the perfect table, the perfect cat, the perfect flower—or the perfect whatever. He was searching for "ideal forms." He knew perfection can't be found on this Earth, but he believed if we try to imagine perfection and then strive for it, we will lead the best lives possible. It is his search for the ideal—the most beautiful and harmonious—that makes Plato a favorite of artists, poets, and mathematicians.

Plato's real name was Aristocles, and he was a descendant

of the early kings of Athens. Because he had broad shoulders, he was nicknamed Platon in school (it means "broad"), and that's the name he carried through the rest of his life. As a young man, Plato traveled and got involved with politics. Later he devoted himself to philosophy, writing, and teaching. His writings are mostly in the form of dialogues—discussions between his teacher Socrates and others.

DUELING IDEAS

The differences between Plato and Aristotle are important; they keep appearing in the history of ideas. Plato was searching for "ideal forms." Aristotle asked questions and then examined existing objects. Plato's philosophy led to deep thinking; Aristotle's, to observation and eventually to experimentation.

Both are necessary. But should one method carry more weight than the other?

Plato (left) and Aristotle talk in Raphael's *The School of Athens* (see also page 73).
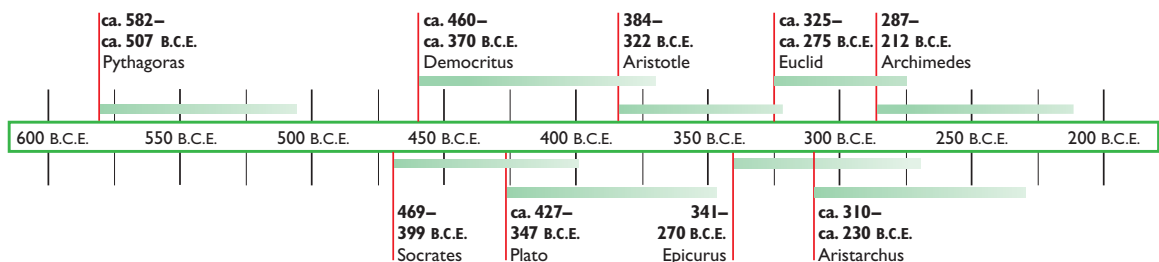
The safest general characterization of the European philosophical tradition is that it consists of a series of footnotes to Plato.

—Alfred North Whitehead (1861–1947), English philosopher, *Process and Reality*
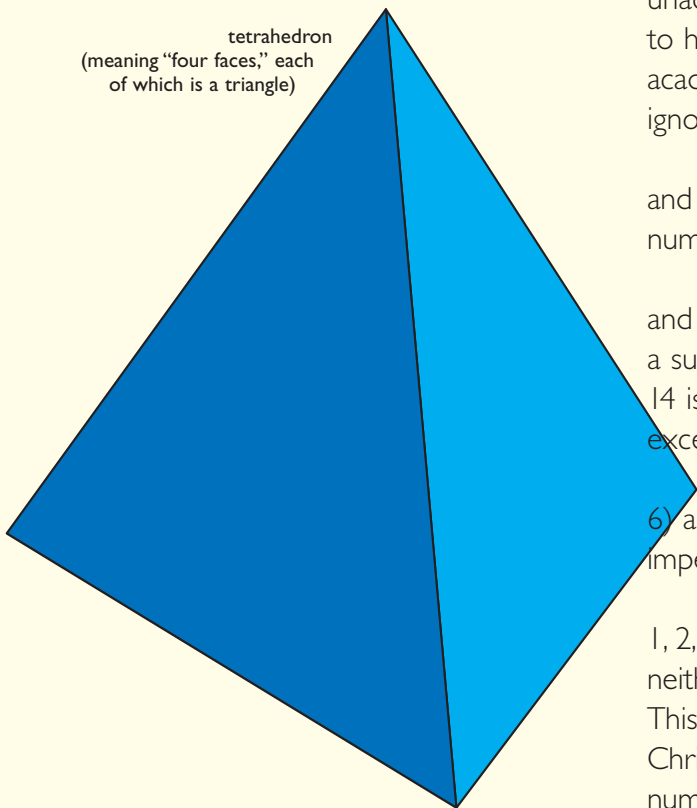
GREEK MINDS MEET AGAIN

Plato was a student of Socrates and a big admirer of Pythagoras. Aristotle was a student of Plato. So what's the point? Young people learn from old people, but sometimes it's the other way around. Science needs new, fresh ideas and approaches to keep moving ahead. It needs the wisdom of experience to use those ideas well.

ca. 582–ca. 507 B.C.E. Pythagoras
ca. 460–ca. 370 B.C.E. Democritus
384–322 B.C.E. Aristotle
ca. 325–ca. 275 B.C.E. Euclid
287–212 B.C.E. Archimedes

600 B.C.E.   550 B.C.E.   500 B.C.E.   450 B.C.E.   400 B.C.E.   350 B.C.E.   300 B.C.E.   250 B.C.E.   200 B.C.E.

469–399 B.C.E. Socrates
ca. 427–347 B.C.E. Plato
341–270 B.C.E. Epicurus
ca. 310–ca. 230 B.C.E. Aristarchus

PLATO, MATH, AND PERFECT NUMBERS

P

lato looked down his aristocratic nose at most natural philosophy (what we call science). It seemed too practical for his mind. He was searching for pure knowledge. So mathematics, which he considered unadulterated thought, had a special appeal to him. Over the door of his famous academy were the words "Let no one ignorant of mathematics enter here."

Plato was fascinated with perfection, and he identified what he called perfect numbers. What's a perfect number?

Consider 14. It can be divided by 1, 2, and 7. Add up those divisors, and you get a sum that is less than 14. Thus, said Plato, 14 is *not* a perfect number. It is known as excessive.

How about 12? Its divisors (1, 2, 3, 4, 6) add up to more than 12. Another imperfect number—a defective.

Now, try 6. It can be divided evenly by 1, 2, and 3. Add them up and—ahh— neither excess nor deficiency. Perfection. This idea outlasted the ancient Greeks. The Christian Saint Augustine wrote: "Six is a number perfect in itself, and not because


tetrahedron (meaning "four faces," each of which is a triangle)

God created all things in six days; rather the converse is true. God created the world in six days because this number is perfect."

The next perfect number after 6 is 28. Then comes 496. After that is 8,128. And after that, 33,550,336. All of them are even numbers, and every perfect that we know ends in 6 or 8.

Now if you're hooked on perfection— and some numbers appear that not only seem imperfect, but are totally weird and unexplainable—well, that could be disturbing. And that's just what happened when the Greeks ran into those irrational numbers (see page 82). You can understand why they found them so upsetting.
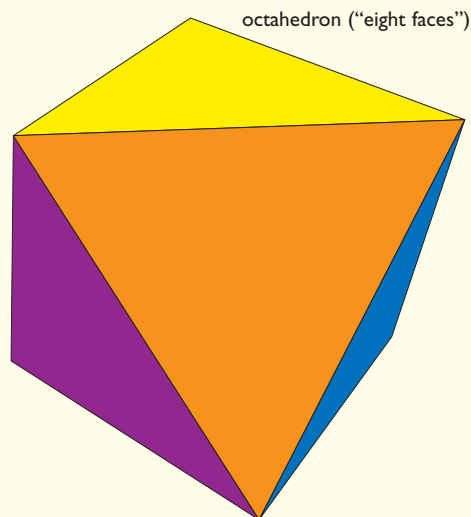
octahedron ("eight faces")

It was actually Pythagoras who discovered these shapes, but Plato made them famous in a dialogue called *Timaeus*, and they are now called Platonic solids. Plato said these are the five (and only five) regular solids with equal lines and angles and faces (all triangles, for example). He saw these solids as perfect shapes, and he was sure the heavenly bodies are exact geometric forms like them. He believed the stars and planets exist in perfect geometric harmony. (Not true, but geometry helps a lot in understanding them.)
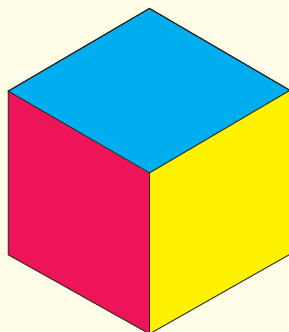
hexahedron
("six faces"—Go ahead and call it a cube.)
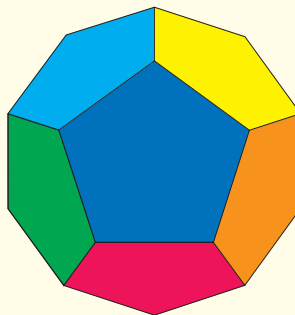
dodecahedron
("twelve faces")
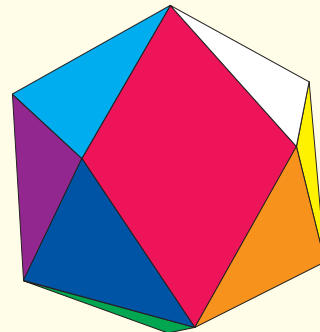
icosahedron
("twenty faces")

An ancient Roman floor mosaic in Pompeii, dating from the first century B.C.E., depicts Plato (in the center, pointing a stick) with his students at the academy.

A **PREMISE** is a statement or idea backed up by arguments. The Latin verb *mittere* means "to send," and so a premise is something sent before.

A marble bust of Alexander the Great (356–323 B.C.E.), made two centuries after he lived, shows him as a youth. Aristotle tutored the soon-to-be "King of Kings" in science and philosophy.

They discussed government, education, ethics and other topics. Plato is probably the most widely read philosopher of all time. As to the academy he founded, it is a model that educators still turn to, agreeing or disagreeing with its premises, but unable to ignore them.

Aristotle was the most renowned of all the academy's students. Plato is said to have called him "the intelligence of the school."

But while Plato was obsessed with mathematics and perfection, scientists toil with the real world, and Aristotle was a scientist. So although he was pulled by Plato's ideas of purity and abstraction, Aristotle had a practical, feet-on-the-ground mind. Aristotle was fascinated with the everyday world around him.

Maybe it was his father's legacy that made Aristotle think as he did. His father had been court physician to

the king of Macedon, but he died when his son was young. Doctors consider problems one at a time. Aristotle would become famous for his well-organized, practical mind. He developed the principles of logic—a system of reasoning that was an orderly way to study astronomy, biology, chemistry, and most of the other sciences. But before he did that, he stayed for many years studying with Plato.

Then, after Plato died, Aristotle was summoned north by King Phillip II of Macedon. (Athens and Macedon were rivals, so this must have complicated the move.) King Phillip wanted the now-famous son of his father's physician to teach his heir, Prince Alexander. That royal tutoring job lasted for eight years and is said to have profoundly influenced the future ruler. When Phillip died, Alexander marched off to become a famous conqueror who would be known as Alexander the Great, a "King of Kings."

Meanwhile, Aristotle had gone back to Athens and started his own academy. He was said to be miffed that Plato had not appointed him his successor. The ideas of those two men— Plato and Aristotle—would eventually lead to different schools of thought. Sometimes there would be harmony between them; sometimes, conflict.

Platonists focus on the life of the mind and those ideal forms. Aristotelians observe the world around them and use

These ruins in ancient Mieza, which was near Thessalonica in Macedon (see map on page 96), are believed to be the remnants of a school for boys from ages 10 to 15. Aristotle taught at the Mieza boys' school from 343 to 340 B.C.E. before joining the faculty at the Lyceum in Athens.

that as a guide for their thoughts. Keep in mind, in ancient Greece, no one seemed to understand the importance of experiments as a way to prove ideas. For the Greeks, including Aristotle, all profound truths could be found in the mind. (Scientists today observe nature, use their minds to form hypotheses, and do experiments to prove or disprove their ideas. It's that last step that the Greeks never quite got. Maybe they couldn't: they didn't have the technology to go far with experimenting.)

Aristotle didn't limit himself to one subject; he considered everything possible—poetry, art, music, math, warfare, ethics, religion, and science. He had a mind like an encyclopedia. Aristotle has been called a great synthesizer. (That word means more than an electronic keyboard.) He made lists of *everything* he could find in nature, and then (this is important) he organized, analyzed, and connected that knowledge. It was a monumental achievement.

Among other things, you can think of Aristotle as the

world's first great biologist. He dissected hundreds of specimens and then wrote about what he saw. He looked at a three-day-old chicken egg, watched the embryo's tiny heart beating, and saw it pumping blood to vessels extending into the yolk. Many of his contemporaries thought he was wasting his time. They believed that only humans were worth studying. Aristotle said, "If any person thinks the examination of the rest of the animal kingdom an unworthy task, he must hold in like disesteem the study of man."

Aristotle's student, the great Alexander, appreciated what his teacher was doing. So when he became king, Alexander sent men around the Greek world and beyond collecting animals. Aristotle put them in what is thought to be the world's first zoo. That gave Aristotle access to a variety of animals that no one had seen together before.

"We must not have a childish disgust for the examination of less admirable animals. For in all natural things there is something wondrous," he wrote.

But knowing the parts of a living thing was not enough for Aristotle: he also wanted to understand how the whole is put together. "For we should not be content with saying that the couch was made of bronze or wood, . . . but should try to

DISESTEEM is low regard or low opinion. **SELF-ESTEEM** is about how you regard yourself. Someone or something you **ESTEEM** is respected or prized.

WHERE ARISTOTLE HAD IT WRONG

Aristotle thought the Earth was at the center of the universe. He said gravity was something that made all objects seek the center of the Earth. He believed the natural state of all objects is to be at rest unless moved by force. He thought heavy objects fall faster than light objects. (This moon experiment, at right, proved otherwise.)

None of that is true. But because Aristotle was so brilliant and was right on many things, his ideas led thinkers astray for many generations. Aristotle came up with some wrong answers, but the important thing to remember is that he asked questions and organized data. A good process for thinking and observing helps us eventually find the right answers—and Aristotle gave us that.

In 1971, astronaut David Scott refuted Aristotle by dropping a hammer and a feather, which both hit the Moon's surface at the same time.

describe its design or mode of composition. . . . For a couch is such and such a form embodied in this or that matter." Aristotle realized that life is more than a collection of parts.

Like the other Greeks, Aristotle thought about light and vision. The Pythagoreans had believed a "visual ray" came out of the eye and hit an object, and that caused sight. (It's actually the other way around: light reflects off objects and enters the eyes.) Empedocles said the eye was like a lantern with an internal fire that went out to illuminate the world. But Aristotle questioned that. (He was a great question asker, as are all good scientists.) He asked: If the eye is a lantern, why don't we see at night? Although he didn't get it right, Aristotle thought hard about light and vision. (Light, so vital to life and yet so difficult to capture and analyze, would become central to twentieth-century physics.)

When it came to astronomy, Aristotle's ideas were mostly wrong, perhaps because he accepted the idea of heavenly spheres, which those who came before him had theorized. Aristotle even added to the total of spheres. He thought there were 54 of them out there rotating and holding the stars and planets. He agreed with the Pythagoreans and Plato that Earth and heaven are different realms following different laws of nature. (Today we know that's not so.) Those wrong thoughts of Aristotle's would be accepted as truth for centuries and centuries to come. Often they would hold back scientific progress. Despite that, we owe him a great debt for the breadth of his vision and the depth of his work.

Aristotle took the ideas of those who had come before him and melded them into a grand theory that attempted to explain

When animal eyes are shining, it's easy to believe there are "lanterns" or "visual rays" inside. But put this lioness in a pitch-dark room (no light whatsoever), and you won't see eyes—or anything. Neither will the lioness. Light has to be present and entering our eyes in order for us to see.

GETTING TO KNOW SOCRATES

He wasn't a scientist, but Socrates was certainly someone to know. We're told that he was ugly—short and stout with a big nose—but his personality, wit, intelligence, and good humor won him wide admiration. He was a talker, and his conversation was famously fascinating. He didn't care about clothes or wealth or worldly goods. So maybe his wife, Xanthippe, had reason to complain. She has come down to us as a shrew.

French painter François-Louis-Joseph Watteau (1758–1823) shows Socrates calmly reaching for a cup of poison while his grief-stricken disciples helplessly look on.

We think Socrates was a student of Anaxagoras. But he was far more interested in questions of ethics (ways to behave) than in learning about the universe. We know he was uncommonly brave. He didn't believe in the ancient Greek gods, who were revered, and he didn't think much of democracy as a system of government. Remember, he was a great talker and he influenced people. How would you feel about him if you were an official in Athens democracy? Socrates was accused of atheism and treason and corrupting the young; he was brought to trial.

Perhaps Socrates could have saved himself, but he refused to do so. He didn't speak in his defense, and a jury of 500 men sentenced him to death. Then he refused to escape when it might have been easy and calmly drank a cup of poison hemlock. His pupil Plato would spend much of his life trying to understand and explain the meaning of Socrates' life and death. We're still considering issues he raised.

and classify everything known. It was an enormous accomplishment, and it set a base for science that is still with us today. Even though many of his ideas turned out to be wrong, the important thing is that he gave thinkers a starting point—something to work with and examine and agree or disagree with. Which is exactly what good thinkers do.